

DISCOVERY OF NUWAITE, Ni_6GeS_2 , A NEW ALTERATION MINERAL IN ALLENDE.

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Introduction: During an ongoing nanomineralogy investigation of the Allende CV3 meteorite, a new mineral, $\text{Ni}_6(\text{Ge},\text{Sn})(\text{S},\text{Te})_2$, was identified in alteration veins in a Type B1 Ca-Al-rich refractory inclusion (CAI) ACM-2, named “nuwaite”. Synthetic Ni_6SnS_2 is well known [1] but synthetic Ni_6GeS_2 is not reported. Presented here is the first natural occurrence of Ni_6GeS_2 , as a new alteration mineral in a CAI from a chondritic meteorite. Field-emission SEM, electron back-scatter diffraction (EBSD) and electron microprobe were used to characterize its composition and structure. The mineral has been approved by the Commission on New Minerals, Nomenclature and Classification of the International Mineralogical Association (IMA 2013-018) [2]. The name nuwaite is after Nu Wa, the goddess in the ancient Chinese mythology who patched the fractured wall of Heaven to save the early World after Pan Gu’s creation, in allusion to this secondary mineral filling cracks in a primitive refractory inclusion in the early solar system. Nuwaite is one of sixteen IMA-approved new minerals from Allende since 2007.

Occurrence, Chemistry, and Crystallography: Nuwaite occurs as irregular grains, 1–6 μm in size, along with mostly grossular and trace of Ge-bearing Ni-Fe metals in alteration veins, or filling some cracks in primary melilite in the CAI. The mean chemical composition of nuwaite is (wt%) Ni 65.33, S 10.29, Ge 8.22, Te 7.88, Sn 5.10, Fe 1.72, sum 98.54, showing an empirical formula of $(\text{Ni}_{5.95}\text{Fe}_{0.17})(\text{Ge}_{0.61}\text{Sn}_{0.23})(\text{S}_{1.72}\text{Te}_{0.33})$. The simplified formula is $\text{Ni}_6(\text{Ge},\text{Sn})(\text{S},\text{Te})_2$. The end-member formula is Ni_6GeS_2 . EBSD analysis reveals that the nuwaite has a $I4/mmm$ superstructure, identical to that of synthetic Ni_6SnS_2 [1], showing $a = 3.65 \text{ \AA}$, $c = 18.14 \text{ \AA}$, $V = 241.7 \text{ \AA}^3$, $Z=2$.

Origin and Significance: Nuwaite in Allende is a new chalcogenide mineral with an intergrowth structure, not related to other minerals. It may be the first solar mineral with high Ge, Sn and Te concentrations, providing new insights into alteration processes of CAIs in carbonaceous chondrites. Nuwaite is also a new material and may be exploited for developing functional materials with intergrowth structures.

Nuwaite is apparently a late-stage alteration product, filling some pore and fracture spaces in the Allende CAI, likely formed after secondary grossular took place. It is probably derived from a sulfidation process, where Ni-Fe metals react with a low-temperature fluid enriched in S, Ge, Sn and Te.

References: [1] Baranov A.I. et al. 2003. *Inorganic Chemistry*, 42, 6667–6672. [2] Ma C. 2013. *Mineralogical Magazine*, 77, 2704.